NATIONAL MISSILE DEFENSE (NMD) TEST PROGRAM

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Abstract

This paper describes the challenging task of testing the most complex, expensive, technically evolving, and politically sensitive missile system to be developed to date. The National Missile Defense (NMD) System comprises radars, interceptors, space-based sensors, and battle management, command, control, and communications (BMC3) elements. While the integration of these many complex elements into a functional system is no small achievement, the performance verification of this system is an equally challenging task.

The NMD Test Program is structured to provide demonstrated evidence of progress toward verifying system-level functional capability. The high cost and other constraints of flight tests require complementary testing and evaluation of the NMD System capability by means of integrated ground testing and simulation. The recent development by the System Engineer of a System Evaluation Plan has provided a key link from the desired system performance, as dictated by the NMD System requirements, to the data items that must be collected during each test. Simulation, integrated ground testing, risk reduction flights, and flight testing are test components whose results will be used to assess system-level performance of the progressively maturing NMD elements and their associated test articles.

This paper describes the test components of the NMD test program, their importance to the test program, relationships among the components, and their contributions to NMD test and evaluation which form the basis for the System Engineer to evaluate and verify NMD System performance.

NMD Testing Challenge

Planning and defining a test program for the nation's ballistic missile defense is a challenge in which government and industry have teamed for over 30 years. The NMD has evolved from a Department of Defense (DoD) major ballistic defense acquisition program—Global Protection Against Limited Strikes (GPALS)—in 1993, to an element-focused Technology Readiness Program, to the current Deployment Readiness Program initiated on 9 April 1996. Also known as "3 plus 3," the program faces a challenge of compressing to 6 years the normal 10- to 12-year acquisition cycle of a typical DoD program. The program will develop, integrate, and test a limited system capability in 3 years that could be deployed in a number of system configurations during the following 3 years. If a decision to deploy the system is not made after the 3-year development, the program would continue to maintain a capability to deploy an NMD System within 3 years after a deployment decision is made while improving the performance and robustness of the system.

Elaborate planning is required to accommodate various challenges faced in conducting NMD tests at various levels. Some of these challenges are as follows: 1) The threat and environment against which the deployed NMD System is designed to operate are unavailable. The targets used in these flight tests are not the true representations of the actual wartime threat. Therefore, to test the specified performance, simulations are extensively used. 2) Elements mature at different rates during their development cycle. This requires a trade between the test schedule, the use of test drivers, and the tailoring of test objectives to accommodate the maturity levels of various elements. 3) The ground and flight tests are scheduled to complement each other. A pre-mission ground test supports the following flight test, and a post-mission ground test uses the data from the preceding flight test to verify various algorithms. Any schedule slip in delivery(ies), lack of specified capabilities in one or more elements, or any other interruption in this cycle breaks the preplanned schedule of test events and requires a complete reassessment of the test program. 4) The Compliance Review Group (CRG) is briefed well in advance on the treaty compliance of the flight tests. 5) Test facilities are planned to ensure that full environmental impacts must be considered and approved.

System/Element Overview

The initial architecture for the NMD System could be in place by 2003 if a deployment is mandated in FY00. This system will meet the threshold values of the User's operational requirements and provide high levels of effectiveness against a limited threat comprising a few simple warheads. The NMD System architecture will comprise several major elements (Figure 1). The Ground Based Interceptor (GBI) is a

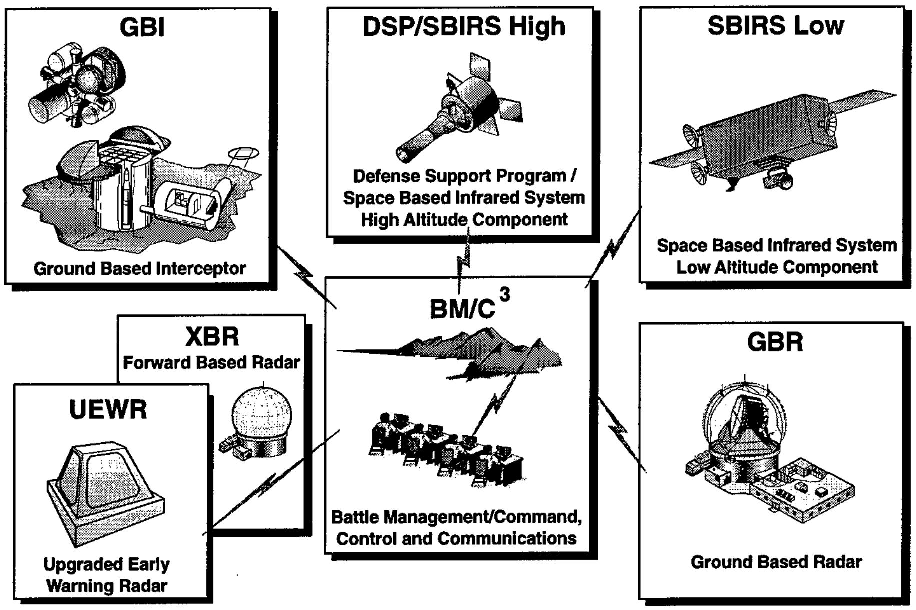

Figure 1. NMD System Elements

kinetic energy exoatmospheric interceptor with long flyout range to provide multiple engagement capability in the midcourse phase of a threat Intercontinental Ballistic Missile (ICBM) flight trajectory. The Ground Based Radar (GBR), or site radar, is an X-band radar that would provide surveillance, tracking, discrimination, and kill assessment data. Upgraded Early Warning Radars (UEWR) extend the NMD battlespace by providing target detection earlier than a single-site GBR. The existing Early Warning Radars (EWRs) could be upgraded to provide this enhanced surveillance and tracking data. The X-Band Radars (XBRs) provide forward-based, high-resolution data from earlier phases of an ICBM's trajectory for surveillance, tracking, discrimination, and kill assessment. The Defense Support Program (DSP)/Space Based Infrared System (SBIRS) High Component satellites maintain continuous global surveillance to detect all ballistic missile launches and provide early warning and booster track data. The SBIRS Low Component satellites will be designed to provide boost and mid-course tracking, discrimination, and hit assessment data. The Battle Management/Command, Control, and Communications (BMC3) element provides essential planning, tasking, and controlling operations of assigned assets. It also provides communications network management, In-Flight Interceptor Communications System (IFICS), and local and wide area communications.

Evolution of Maturity and Integration

A progressive plan is laid with a build-up of system-level integrated testing using simulations, ground tests, and flight tests with threat-representative targets. NMD System maturity and capability evolve through an incremental and logical build-up sequence of critical interfaces and system performance. The incremental build-up of tested capability integrates element development items (representations) using early representations for unavailable elements. Element test article representations evolve from models to functional representations, to actual hardware and software processors that are used for element and system physical integration and test.

Verification of Technical Performance

System assessment begins with functional testing of integrated element models and their test drivers to check out algorithms and validate the concepts. Assessment, then, progresses to real-time simulation to evaluate timing and Human-In-Control (HIC) aspects. Physical and logical interfaces are tested using maturing element hardware and software as available, and integrated either in a contractor laboratory or through use of a wide area network distributed test. System-level testing capitalizes on planned element tests through collecting the appropriate data early. This data is used, subsequently, in effectively planning and conducting the dedicated system tests to verify system performance. These tests have deployable element representations and are tested in configurations and scenarios supporting technical and operational performance requirements. Integrated flight tests (IFTs) confirm the performance of actual elements in a live-range setting using a limited threat scenario, while ground

tests extend the performance demonstration through element hardware-in-the-loop (HWIL) representations and to full operational scenarios. Figure 2 depicts the four components of the NMD Test Program, i.e., simulation, ground testing, flight testing, and risk reduction flights (RRFs). Before discussing these components, we will provide background regarding the unique NMD testing limitations and constraints and an overview of the test planner/system engineering process.

Limitations and Constraints For Testing

A brief discussion will reveal why considerations for test planning and conduct are made to mitigate various limitations and constraints. Replicating total system realism and performance is bounded by the unique characteristics of the NMD elements and the system test infrastructure. The following descriptions will further exemplify the characteristics of the NMD test program. Integrated testing depends on availability of element test articles, their functional capabilities and maturity levels, and resources. Due to the high cost and complexity of flight testing, resources are planned to maximize their value, and integration opportunities are planned to minimize cost and schedule impacts. Because of budget and time constraints, targets are constructed to be as representative as practical of the threats postulated for the deployment time frame. Consequently, to physically test all engagement variants against actual threats, a major focus must be simulation and emulation development. Due to the nature of ballistic missile defense, environmental pollution prevention and treaty compliance must be planned for in all tests. Another consideration recently realized is that since the full complement of HWIL and software-in-the-loop (SWIL) test article quantities is not affordable, testing full capability architectures is limited. Therefore, analysis and simulation are used to augment testing.

Test Program Overview

The test program is flexible in order to embrace each step or degree of system performance as the elements mature. The high cost and the constraints of flight testing place the burden of evaluating the NMD System capability on the ground tests and simulations. As element developers produce test articles and prototypes on their developmental schedules, representations with increasing levels of fidelity are used for integrated system testing. Modeling and simulation, Integrated Ground Test (IGT), IFT, and RRF results are used to assess system-level performance as the elements and their associated test articles mature. The NMD System test program achieves flexibility by providing a system-level assessment of integrated element performance at progressive levels of maturity.

As system integrated tests are conducted, the results are evaluated against test predictions and performance measures derived from the critical technical parameters (CTPs) and critical operational issues (COIs). The evaluated integrated results are combined with element test results to adjust the plans for future tests. Results of these element and system tests support periodic appraisals of demonstrated capability and confidence measures by the NMD System Engineer.

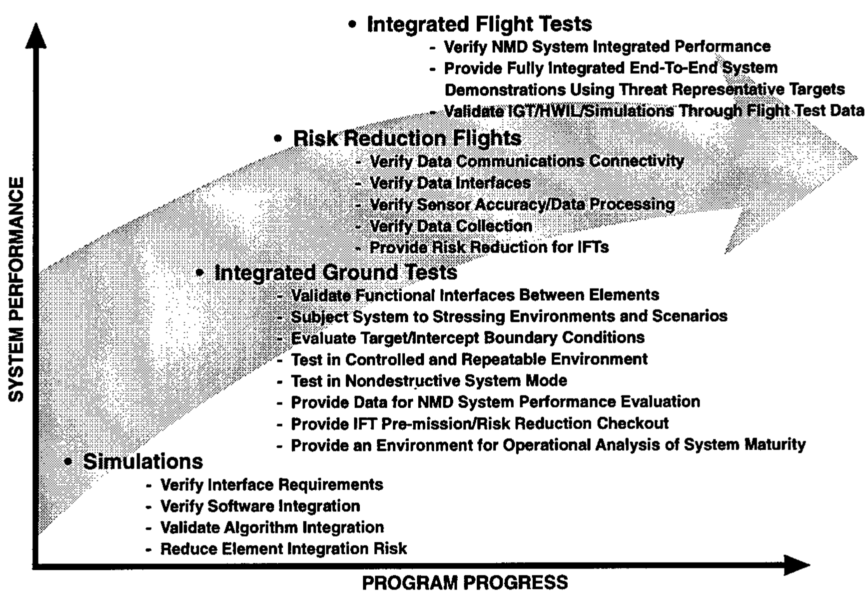

Figure 2. Components of the NMD Test Program

The System Evaluation Plan (SEP), developed by the System Engineer, delineates the methodology for evaluating the performance of the NMD System in preparation for the Deployment Readiness Review (DRR) in FY00. The SEP is derived from the Capability 1 (C1) System Requirements Document (SRD) and defines technical performance measures (TPMs) that summarize system performance in eight critical areas. These TPMs and their evaluation are supported by 101 subordinate, related evaluation parameters (EPs). These EPs have been selected from the 633 "Perform NMD" requirements in the C1 SRD based on how sensitive the negation probability would be to the parameters' variation and the level of technical concern within the community. For each of these EPs, the SEP identifies test data categories and specific test data items that must be collected for the System Engineer's performance analysis.

These specific data items are further decomposed by the test planners to identify test data requirements for each integrated system level test. Coordination of these requirements with the element developers is vital to assure the availability of all needed data. The final data requirements for each integrated test are subsequently captured in an Integrated Test Plan (ITP) that serves as the basis for individual Detailed Test Plans (DTPs) developed by the test executors.

Data collected in accordance with these requirements is then used by the System Engineer to support analyses that generate estimates of the current level of system performance relative to the C1 SRD required levels. The confidence in these performance estimates improves as the capability, fidelity, and maturity of the element representations tested increase.

Simulation in NMD Test Program

Importance of Simulation to the Test Program

The importance of simulation and HWIL testing comes from their repeatability, controllability, and cost effectiveness. The NMD System, because of its unique nature, does not lend itself readily to comprehensive field tests and demonstrations. Testing is necessarily limited by the impracticality of fully duplicating the threat and the tactical environment. As a result, system performance evaluation and requirements definition must rely on simulation. Simulation provides a link to connect the performance of interceptor elements with the NMD System performance requirements. Top-level requirements, operating concepts, and scenarios of battle action are generated at the system level and are carried down in greater levels of detail and allocation to the next level of detail. Highly detailed models of proposed technologies are carried upward to performance function models, which are compatible with and supportive of the element models.

Contribution of Simulation to Test and Evaluation

Simulation has contributed to T&E activities in monitoring system requirements, extending the boundary envelope of the system under evaluation, collecting data for model validation, and providing data for analyses to support deployment decisions. Simulations in the test program support three major areas: 1) system requirements analysis, 2) design performance analysis, and 3) flight test analysis.

System requirements analysis involves system effectiveness studies for different scenarios and one-on-one threat analysis. Topics include the force operational placement effectiveness and netted distributed replicated architecture trades. Also included are verification of Single-Shot Kill Probability, weapon target pairing, surveillance management, kill assessment, discrimination and threat typing, and, in general, battle management.

Design performance analysis serves to verify element B-specification requirements, verify BMC3 performance, and provide subsystem performance budget analysis and coverage analysis. System statistical performance consists of Monte Carlo analysis to show statistics on IFTUs, kill vehicle propellant remaining, miss distance, and a host of other measures-of-effectiveness parameters. This leads to an evaluation of subsystem Single-Shot Engagement Kill Probability (SSEKP) performance evaluation and an evaluation of system-level drivers, such as radar and launcher saturation.

The focus of data analysis from flight tests using simulation will be, primarily, to show compliance with the element and interface specifications. The goal is to meet the specific flight test objectives. Requirement flow-down started from test objectives and sub-objectives designated for each individual test. Traceability must extend to the system level test and data requirements as well as Developmental Test and Evaluation objectives. Figures, tables, and discussions in an analysis report must clearly demonstrate this traceability.

Simulations are used to assess element functional performance in specific areas. For radar and infrared sensors, the analysis may include tracking position and velocity accuracy, launch and intercept point estimation accuracy, threat discrimination, and kill assessment analysis. For interceptors, assessment may include seeker signature and data processing, guidance, naviga-

tion and control, aerodynamics, telemetry, in-flight guidance update, and threat object map processing. For the BMC3 element, the functional analysis will extend to cover threat evaluations, sensor and track management, weapon management and assignment, engagement control, HIC, discrimination, kill assessment, and command, control, and communications. At the system level, simulations support the assessment of protection effectiveness, event timelines, kill assessment, system interfaces, and operational connectivity. Additional uses for simulations are found in test scenario development, target and threat trajectory and signature analysis, and lethality analysis. Simulations are used to extend from one-on-one and few-on-few real life flight test scenarios to many-on-many system effectiveness analyses.

A number of simulations are used for threat scenario generation, weapon system engagement, and high-fidelity system simulation, including BMC3, communications, radar, and missile. BMDO has accredited software to support terminal endgame lethality simulation, which models body-to-body and fragment kill of ballistic missile payloads from kinetic energy weapon attack. There are also scenario generators to model many objects, including threat target reentry vehicles, boosters, fragments, and interceptors.

Relationship of Simulation to Integrated Ground and Flight Testing

Simulations are conducted for mission planning and for predicting the IFTs' results. The HWIL IGTs are run to provide confidence in flight test execution and in deriving detailed data requirements. After a flight test has been conducted, the assessment is completed with the release of a test execution report and a Post Test Analysis Report, and data is subsequently released to the BMD community. Data from flight tests also serves to validate the models used in simulations and HWIL tests. The validated models serve to extend the performance boundary from few-on-few to many-on-many threat and interceptor scenarios/trajectories. The pre-test and post-test relationships to the flight test are shown in Figure 3. Simulation and HWIL testing provide high confidence in system performance. This confidence is increased as IGTs are validated by flight test data comparative analyses as the NMD test program progresses.

Ground Testing in NMD Test Program

Importance of IGTs to the Test Program

An NMD IGT is a type of test involving one or more NMD element test articles operating in a system context in a nondestructive mode. A test article consists of the actual element operational software (SWIL) operating within the actual data processing hardware (HWIL).

IGTs provide the opportunity for system elements to interact by physical or phenomenological stimulation. The primary roles of IGTs are to:

- Provide IFT pre-mission/risk reduction checkout
- Validate functional interfaces between elements

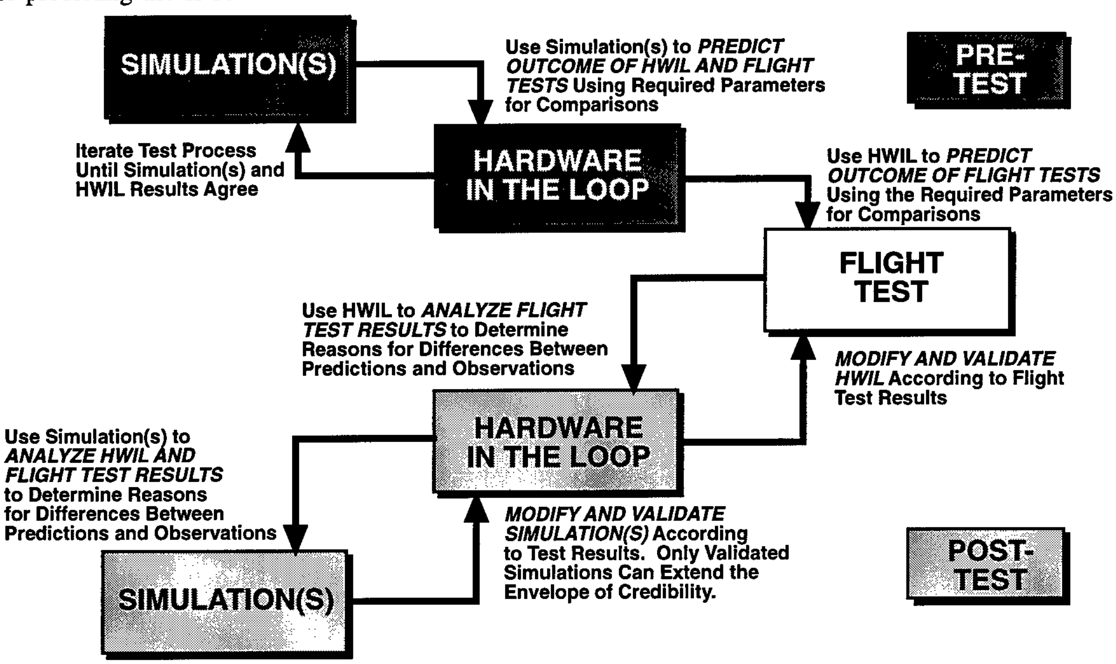

Figure 3. Pre and Post Test Relationships

- Subject system to stressing environments and scenarios
- Evaluate system capabilities over tactical battlespace
- Test in a controlled and repeatable environment
- Test in a nondestructive system mode
- Provide data for NMD System performance evaluation
- Provide an environment for operational analysis of system maturity.

IGTs generate comparative IFT test data to validate a portion of the NMD performance envelope represented by each test configuration. The IGTs are used to extend the scope of IFTs, evaluate system performance at the edges of the engagement envelope, and combine hardware and software development in realistic system configurations. IGTs are repetitive in nature. This provides the tester with a method to collect sufficient data to gain confidence in the system.

Contribution of IGTs to Test and Evaluation

IGTs benefit the NMD test program through testing the evolving system configuration using simulation/emulation and real data processing hardware/software. HIC, simulated real-world threats, global and local environments, and multiple elements interact. IGTs provide valid and useful test data, a wider range for testing at a far lower cost than a comparable IFT, and an opportunity to analyze "what-if" criteria for meaningful assessments of element capabilities when merged into a system. IGTs, distinct from IFTs, are standalone tests, capable of providing multi-run test data.

Relationship of IGTs to Simulation and Integrated Flight Testing

Used as pre-mission risk reduction measures, IGTs provide confidence in IFT execution by predicting element performance, exercising interelement interfaces and message exchanges, and affirming the ability to provide the required data. Ground testing reduces the uncertainties associated with flight tests to only those that must be resolved through actual flights. IGTs are used in a post-mission mode to assess achievement of IFT objectives and to investigate anomalies.

IGTs are used to evaluate the performance of the evolving objective system in operational scenarios that cannot be tested in IFTs due to constraints such as engagement geometry, multiple object attack scenarios, and nuclear environments. IGTs provide a wider range of testing at lower cost than IFTs, yet retain realistic element inter-operation with human operator participation.

The primary NMD System-level ground test tool is the Integrated System Test Capability (ISTC), located at the Advanced Research Center (ARC). It is a computer-based system for testing actual NMD element data processors (HWIL) and software (SWIL) in an integrated configuration through the use of a common test environment. The ISTC's function is to test functionality, reliability, operability, and interoperability of embedded computers within integrated elements of the NMD System. Individual elements of the NMD System are represented in the ISTC on computer stations, known as nodes. Each node incorporates actual element mission and communications processors, running actual element software. A system communications network driven by real-time system interfaces interconnects the individual element nodes and threat and environment input data. Separate ISTC networks controlling the test configuration and providing the environmental data also connect the nodes. The ISTC infrastructure supplies each autonomous node with a simulated threat and associated environments, natural and man-made, which are consistent for each NMD element in the test scenario. In this manner, ISTC exercises the entire NMD System simultaneously.

The embedded element processors are the NMD "tactical hardware" being tested in the ISTC. The ISTC interfaces directly with the actual BMC3, so that system level operability issues can be addressed. It accurately represents actual tactical communications messages in terms of timing, format, and content, allowing testers to resolve connectivity and interoperability questions.

The primary roles of ISTC are to:

- Support the evaluation of the system performance of the NMD System:
  - Test a broad range of threat scenarios with multiple engagements
  - Test multiple sensor operations such as correlation and discrimination
  - Test system recovery from failures and casualties
- Determine the interoperability and reliability of the deployed software in the NMD System:
  - Verify the NMD System interfaces
  - Conduct extended tests to determine software reliability
  - Drive the integrated NMD in all of its modes of operation
- Exercise HIC to the extent planned in the NMD System:
  - Exercise actual command centers and operators in the loop with stressing scenarios.
- Extend the envelope of flight testing:
  - The size of the threat
  - The types of threats

  - Complex and multiple engagements
  - NMD System operation in the presence of the full range of natural and hostile environments
- Support Integrated Flight Tests:
  - Reduce the risk of conducting a flight test
  - Determine the test article readiness by exercising it in a system environment
  - Verify the test plan by simulating the test and displaying the expected results
  - Confirm test integration by stimulating the test assets to verify readiness.
  - Support post-mission analysis
  - Integrate all recorded data and reconstruct the test
  - Provide representations for missing elements.

Risk Reduction Flight (RRF) Testing in the NMD Test Program

Importance of RRFs to the Test Program

RRFs (formerly called targets of opportunity) are important to the NMD test program for two reasons: cost and schedule. Flight testing becomes increasingly expensive as element representations mature and as the test support instrumentation augments each test. Therefore, test configurations, test integration, procedures, and control are more complex with each successive IFT. An RRF maximizes the use of all the parts available for the IFT with the exception of two high-dollar items, the interceptor and the NMD validated target. Because the RRF is nondestructive, most of the IFT end-to-end connectivity can be checked out for a relatively fractional cost of an IFT. Secondarily, with a 3 plus 3 deployment-readiness fast-track schedule, each test must be supportive of the program development or deployment schedule. Due to the key role of the flight test program, RRFs expand the operational test opportunities. Additional flights are planned to support element and system level risk reduction. RRFs are scheduled to complete the development of the NMD test infrastructure and, in some cases, supplement the element development tests. To this end, RRFs serve as an efficient component of the NMD test program to maximize NMD dollars and augment the planned integrated ground and flight tests.

Contribution of RRFs to Test and Evaluation

The contribution of RRFs to the NMD test program can be recognized in their use as an element or system tool. RRF events provide results on sensors, BMC3, communications connectivity, and test infrastructure that is valuable to overall risk mitigation and system evaluation. The use of RRFs is specifically identified in the SEP evaluation plans. These flight test resources, coupled with IGTs and model and simulation analyses, provide a full spectrum of tools to validate, verify, accredit, and evaluate NMD System performance in support of the NMD Deployment Readiness Review (DRR). Although this paper focuses on system-level testing, an RRF may be utilized by a single element or in a context of less than a complete system. For example, a sensor element may require an RRF to check out functional or physical interoperability, to perform sensor analysis, or to verify other element requirements. There are various ways that an RRF can address and/or resolve test or program needs for the system level. The following describes some uses: 1) perform assessments and quick look analysis of the IFT test conduct, 2) perform post test analysis addressing objectives for the following IFT, 3) address T&E data nominal/anominal requirements, 4) address "holes" in the IFT results. RRFs have flexible requirements and objectives that can be tailored to specific needs for element or system test risk reduction.

Relationship of RRFs to Simulation and Integrated Ground and Flight Testing

Inherent in the current planned NMD test program are RRFs, which provide a cost effective approach to reduce program risk. RRFs have been successfully used in the past to support development objectives. The RRF test program leverages off non-NMD existing flight tests or other separate targets of opportunity where available NMD element representations are run on-line. Essentially, the RRF test configuration "piggybacks" off targets of opportunity such as a Multi-Service Launch System (MSLS) or a ballistic missile Follow-On Test and Evaluation (FOT&E) flight test. The target flight opportunity allows the evolving NMD test architecture to participate in an "associate operations" role with the target test program's office of primary responsibility. Through this relationship, an RRF provides an operational environment by which each element, in a system configuration context, examines interoperability with other elements and the external systems. Target flight schedules are assessed to allow RRFs to be conducted prior to IFTs. An RRF provides a vehicle to exercise and test IFT configuration, verify uprange element integration prior to the IFT mission, and verify real-time test procedures. An RRF supports pre-mission testing by providing both recorded and live flight test data. This data is used to drive the HWIL IGT test setups to reduce risk.

Flight Testing in the NMD Test Program

Importance of IFTs to the Test Program

Flight tests verify NMD System performance and provide fully integrated end-to-end system demonstrations in the real world using threat representative targets. IFTs also demonstrate end-to-end target detection, acquisition, tracking, correlation, and hand-over performance; demonstrate real-time discrimination performance; and demonstrate NMD System kill assessment capability. In addition, flight tests demonstrate the ability of the NMD System to develop and coordinate battle management plans; prepare, launch, and fly out a designated weapon, and kill a threat representative target. They also demonstrate integration, interface compatibility, and performance of the NMD System, subsystem hardware and software, and HIC operations and present a strong contribution to NMD System effectiveness and suitability.

Contribution of IFTs to Test and Evaluation

Flight tests provide data to verify that system requirements and performance objectives have been met. They allow an incremental development process with a test-as-you-go philosophy. This provides assurance of system maturity prior to moving into the next development phase and prior to authorization of subsequent development and deployment expenditures. Flight tests replicate, with an increasing degree of accuracy, the actual operational use of the system. They allow the actual operators to have hands-on experience prior to actual deployment and combat use.

Flight tests demonstrate that errors can be zeroed in performing Hit-to-Kill (HTK) intercepts and provide data to allow for optimum allocation of response time to verify speed, propulsion, capability, and maneuvering. Flight tests also demonstrate that integration and interface requirements have been satisfied, and that the interactive effects of the interceptor, target, NMD elements, and environment variables are accounted for in a flight environment. In addition, flight tests contribute to the verification of lethality, probability of hit, probability of kill, target debris, and mission reliability.

Relationship of IFTs to Simulation and Integrated Ground Testing

A complex system like NMD cannot be thoroughly flight tested throughout the performance envelope because of test limitations and cost. Each flight test costs in excess of $50M, which severely limits the number that can be conducted. At the test range, a tactical site cannot be replicated because of physical constraints, and range safety governs the selection of intercept points. Therefore, a practical approach must be conceived to supplement flight tests with ground tests. Historically this has been accomplished by simulating the system, validating the simulations with flight test data, and then using the simulations for extended performance and statistical testing. Using a combination of HWIL, SWIL, and simulations, ground tests are used to test the total engagement space and threat spectrum. They assess the functional interfaces between the elements, subject the system to stressing scenarios such as many on many, and evaluate target-intercept boundary conditions. IGTs are conducted in controlled and repeatable environments in a non-destructive mode. They help to identify "unknown unknowns" in an interactive system context, and they verify interoperability of NMD System elements throughout the system's performance envelope. Flight tests cannot do this. Series of IGTs are conducted with tactical configurations (representations, simulations and HWIL/SWIL) to generate management decision data. In addition to ground tests, simulations provide representations of elements that are not yet mature enough for the flight test program and representations of complex environments, helping to overcome limitations in actual flight testing. Simulations verify interface requirements and software integration, validate algorithm integration, and reduce element integration risk. Simulations will be employed to effectively repeat data points in order to improve the statistical sample or to determine overlooked or directly unmeasured parameters. Flight test data validates ground test design, results, HWIL, and simulation fidelity.

Evaluation of Test Results and System Performance

This section describes the analysis relationships specifically among IFTs, IGTs, and system performance evaluation. Common features between IFTs and IGTs, the process for analyzing the features, and external document support are also discussed.

Purpose

The purpose of post test analysis is to verify that the NMD Program T&E objectives have been attained and data collection requirements have been met. The resulting data is verified against T&E objectives that are agreed upon at the test design review. The System Engineer can then use this data to assess progress toward required system performance. T&E objectives are derived from two sources: the Integrated Test Plan, which provides test objectives flowed from the TEMP

for scheduled tests to be conducted during the specified fiscal year test program, and the System Requirements Document, which provides detailed test and analysis requirements.

Relationships

Ground tests and flight tests are analyzed by comparing the test results against the test objectives. Success and increased confidence for each test result begin with a commitment to early involvement in all test activities. Pre-mission activities provide interaction with test operators, thereby providing opportunities to refine analysis procedures, influence test execution, and optimize the test results. Involvement continues with engineering judgment of the cause of and estimates of the accuracy of each test result, the presentation and reporting of the findings, and interaction with the system performance evaluation process. System performance evaluation is the process of determining progress toward attainment of system performance requirements. This process involves the evaluation of data from system- and element-level models and simulations, analyses, demonstrations, and inspections. Post test analysis supports the System Engineer in this activity by the submittal of individual test results in a manner such that they may be used to rebalance test objectives, performance requirements, and future tests.

IFT/IGT Commonalities

Although IGTs and IFTs hold unique attributes, a common thread exists in the post test analysis of the test results. IFT and IGT commonalities include: mission profiles, timelines, and message traffic. For each of these test categories, data sets collected as truth, planned, and observed data are compared as a significant part of the analysis. Figure 4 displays how truth data is compared with observed, planned is compared with observed, and truth is compared with planned. Truth data is defined as data that characterizes the actual occurrence of an event with respect to a predefined reference coordinate system. Examples of truth data include DSP and MSLS source data. Planned data is defined as a-priori data that anticipates the occurrence of an event constrained by a limited set of assumptions. Examples of planned data include simulated and pre-mission source data. Observed data is defined as a-posteriori data that is measured or calculated as a result of the occurrence of an event and is constrained only by environmental and test architecture conditions. Examples of observed data include position and velocity state vectors.

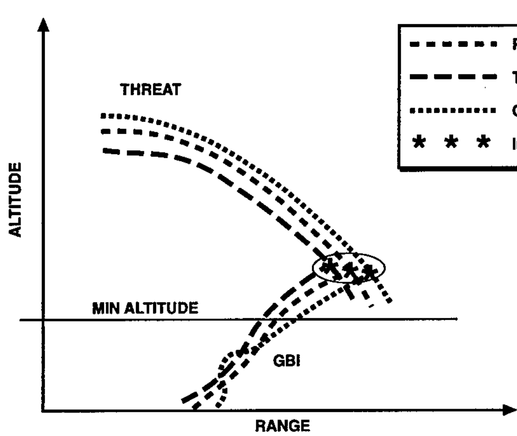

Figure 4. Data Comparisons

The time sequence of events is also assessed within the recorded data. Interactions among element representations are evaluated. Engineering anomalies and statistical estimates of the causes with respect to individual tests are assessed and presented in a format for the System Engineer to conduct system performance evaluation. In this framework all test data is statistically and comparatively analyzed, identifying potential program shortcomings requiring corrective measures.

Analysis Process

Typically the post test analysis process consists of activities in four major areas: data preparation, data qualification, data analysis, and post-test analysis reporting. These activities are sequential, supporting each subsequent step in the process shown in Figure 5. Data preparation consists of conversion of binary (raw) data to ASCII (text) data and template formatting for data base management. Data qualification consists of management of censored, truncated, missing, or outlier data. Data analysis reduces all test data to meaningful results with respect to the test objectives. Post test analysis reporting publishes and distributes the findings through hardcopy and electronic media. Specific analysis is performed in the following areas: coverage analysis, timeline analysis, and message analysis. Coverage analysis spans NMD defense coverage of each of the 50 United States. Timeline analysis measures the occurrence and response of critical NMD events. Message analysis tracks the source and destination of NMD message contents that stimulate and respond to coverage functions and timeline parameters.

The post test analysis process provides statistical and comparative analysis of truth, planned, and observable test data. Message contents, timelines, critical test parameters, and other data are analyzed to produce measurement error and specification deviations. Error and deviation output is cost-effectively generated with

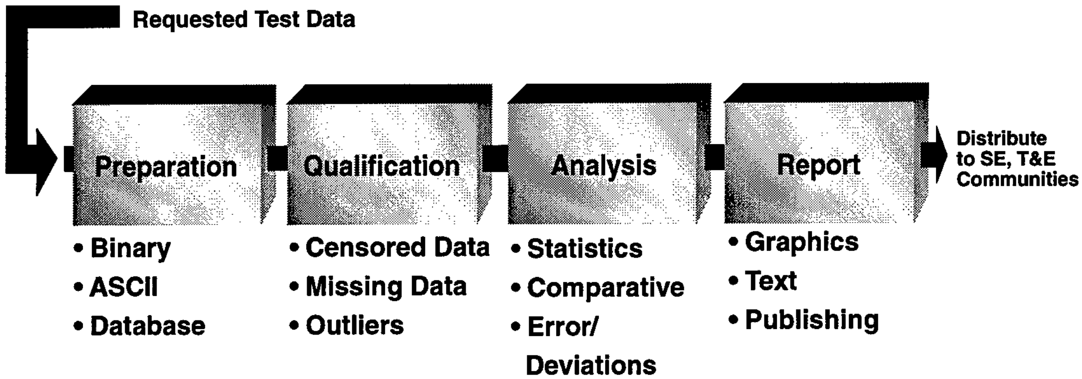

Figure 5. Post Test Analysis Process

commercial-off–the-shelf (COTS) software resident on a network of Windows- and Unix-based platforms. This value-added configuration eliminates the need for expensive and time-consuming new development of the analytic tools and decreases technical risk by utilizing industry-standard COTS software.

Routine outputs from the COTS software (tabular, histograms, scattergrams, distribution plots, etc.) are collectively assembled, correlated, and interpreted as specific test results from each individual IFT and IGT test series. Industry-standard word processing COTS software completes the process of publishing the test results as interim and Final Post Test Analysis Reports (PTARs).

Each PTAR aggressively supports the system engineering evaluation process with the inclusion of step-by-step achievements of each specific analysis for the test objectives. These contents and the analyzed data are used by the System Engineer to assess the attainment of system performance requirements and are further used to rebalance test objectives, performance requirements, and future tests.

Document Support

Post test analysis aggressively supports and reviews the spectrum of compliance documents (TEMP, SRD, SEP, DTP, etc.). These documents drive the IFT and IGT developmental tests, test objectives, and data requirements that produce the recorded data. The data is then assessed according to the SEP requirements such that the system engineering evaluation process advances towards successful program completion.

The source for all collected data (truth, planned, observed) is identified in the appropriate Data Management Plan. The conditions under which the data is gathered and the format to be used for test-objective data presentations are then developed. These presentations may take the form of tables, graphs, curves, bar charts, and others. This decomposition is executed for all IFTs and IGTs.

Progress in achieving DT&E program objectives, threat assessment, and demonstrated maturity of the NMD System are key milestones for the NMD Deployment Readiness Review. IFT and IGT test objectives represent a subset of the DT&E objectives. Source documents (ITP, SRD, etc.) contain the objectives and are decomposed into sub-objectives and data requirements for each decomposition. From this process, measurable parameters are extracted whose evaluations are ultimately presented as evidence of attainment toward the NMD System objective.

Test Challenge Accepted and Pursued (Summary)

Testing a system as complicated and vital as the NMD System is challenging, but not formidable. The test program discussed herein implements processes developed for allocating test requirements, executing testing, and performing test analysis and evaluation. Further, system technical performance measures and test objectives are addressed in progressive incremental integration of elements in test configurations for FY97-FY00. The NMD System capability is demonstrated through verification of interface compatibility, interoperability, and integrated performance of the elements. The NMD test program focuses on deployment readiness through complementary integrated flight testing, integrated ground tests, simulation, and risk reduction flight tests. A Lead System Integrator has been selected and given the authority to proceed to execute a test program that provides increasing confidence that we will meet the NMD challenge and be ready for a deployment decision in FY00.